Orange Juice: Will it be Available to Drink in the Future (Agriculturally or Commercially)?

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Southern Gardens is a wholly owned subsidiary of the US Sugar Corporation, with three orange groves located in southern Florida, near Lake Okeechobee, where we have a 20-million-box capacity processing operation (Figures 1 and 2). In a given year, we squeeze 10% to 15% of all the oranges grown in Florida: 25,000 oranges a minute producing 600,000 gallons a day. We store the juice in million-gallon tanks of which we have 56 that we turn twice a year.

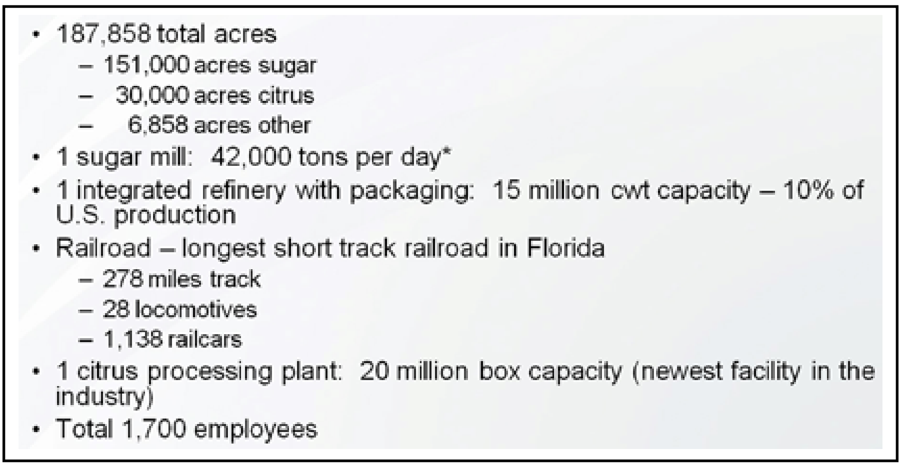

Figure 1. Corporate assets of the US Sugar Corporation.

Citrus Greening (HLB)

Citrus greening—an insect-vectored bacterial disease, also known as huanglongbing (HLB)—was first detected in Florida in 2005 on the heels of the citrus-canker eradication program, which elicited a widespread aversion to tree removal. After a 2009 study, the National Academy of Sciences identified citrus greening as the most serious disease challenge they had ever reviewed (NRC, 2010).

Figure 2. Southern Gardens citrus-processing plant.

Figure 3 shows the symptoms: yellow shoots, mottled leaves and dead trees. Mineral and nutritional deficiencies, and so on, can produce similar symptoms (Figure 4), which creates a problem.

Figure 3. Gross symptoms of citrus-greening disease.

Figure 4. Nutritional/mineral-deficiency symptoms.

The fruit is misshapen, normally smaller—operative word "normally"—and more and more mature fruit are showing infection (Figure 5).

Figure 6 illustrates the challenge of finding early symptoms. The insect carrying the pathogen—*Liberibacter* spp.—is as prevalent in Florida as the mosquito. When it feeds on an uninfected tree, it can be up to two years before the tree has symptoms.

In October of 2005, we owned one of two commercial groves in which the disease was confirmed. Although we knew little of the disease, we had to be as proactive as possible. By January of 2006, we were in Brazil where the disease had been diagnosed 18 months previously.

The state did a sampling to identify where the disease was in Florida. Figure 7 shows the progression.

Today, every citrus-producing county in Florida is infected. Figure 8 illustrates how rapidly it has spread through one of our groves; each block is 10 acres, and each spot is a GPS coordinate of a tree that was identified as infected and removed. To date, we have lost 30% of our acreage. We are the largest grower and processor of oranges in the state that is vertically integrated. We have identified in excess of 700,000 trees that are infected by this disease. Figure 9 shows the level of infection in Florida through 2011. The data apply through 2011 because, basically, the industry has quit tracking the progression of the disease. We can say, with reasonable certainty, that the infection rate is 100% in the Florida citrus industry; not every tree is infected, but 100% of the groves are infected.

Figure 5. Fruit symptoms of citrus-greening disease.

Figure 6. Symptoms in the grove.

Best Practice

This disease has been in the citrus industry for years, in the Far East and elsewhere. The program that everybody started to follow was to inspect groves frequently—four times per year—aggressive roguing of infected trees, and full-time scouting for the Asian citrus

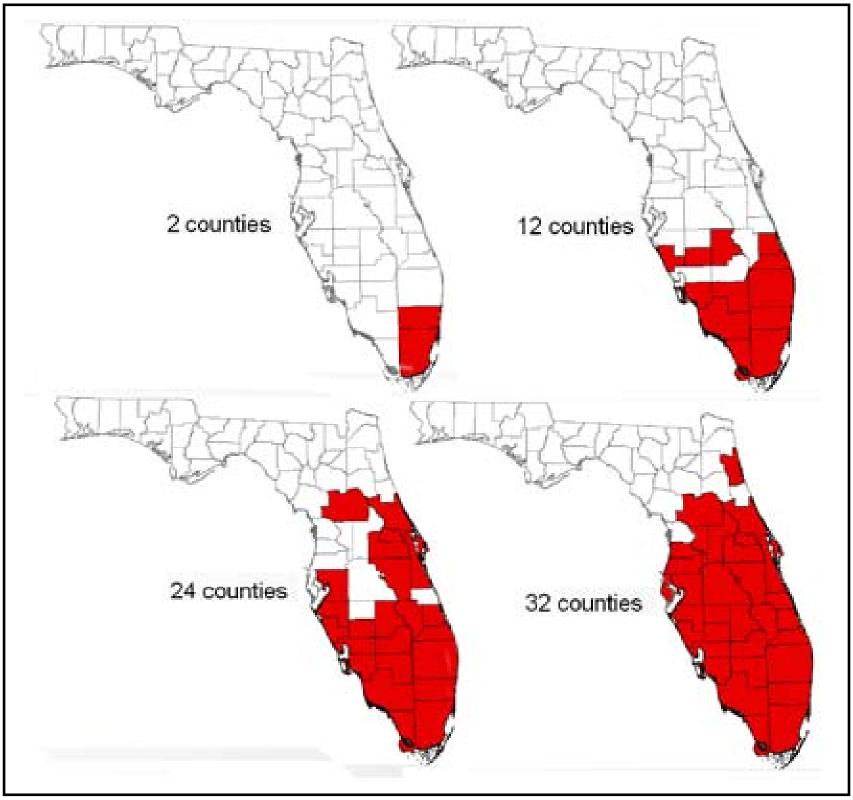

Figure 7. Spread of citrus greening, October 2005, April 2006, January 2007, to June 2007.

psyllid, *Diaphorina citri*, the vector. The industry is working hard to control the psyllid with aggressive applications of insecticides; however, we have learned that tolerance for the insect is less than zero. You have to assume it's there. If you do nothing until you find it, then it is too late. Our growing costs have risen by over 40%, whereas our juice prices haven't gone up by 40%.

Challenges

Should different strategies be chosen in high-inoculum-load areas in comparison with low-inoculum-density areas? Such decisions have to be made "on the fly" and on a large scale. Relevant questions are:

How long will a grove remain economically productive after the disease is detected?

Will replanted groves be disease free? If not, is there a time horizon or will the disease be there forever?

At which point should nutritional approaches be tried?

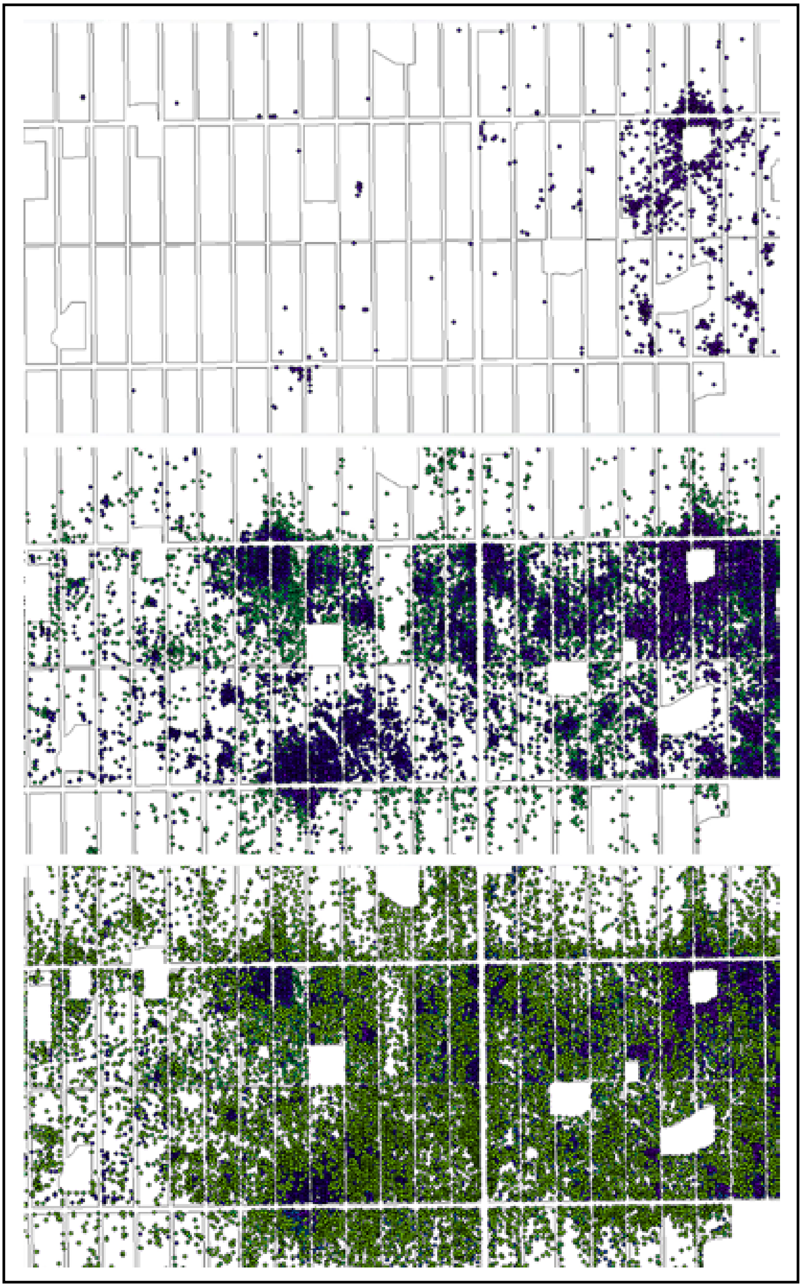

Figure 8. How rapidly does citrus greening spread? Top, Oct. 2005–Mar. 2006; Middle, Oct. 2006–Mar. 2007; Bottom, Aug. 2007–Oct. 2007.

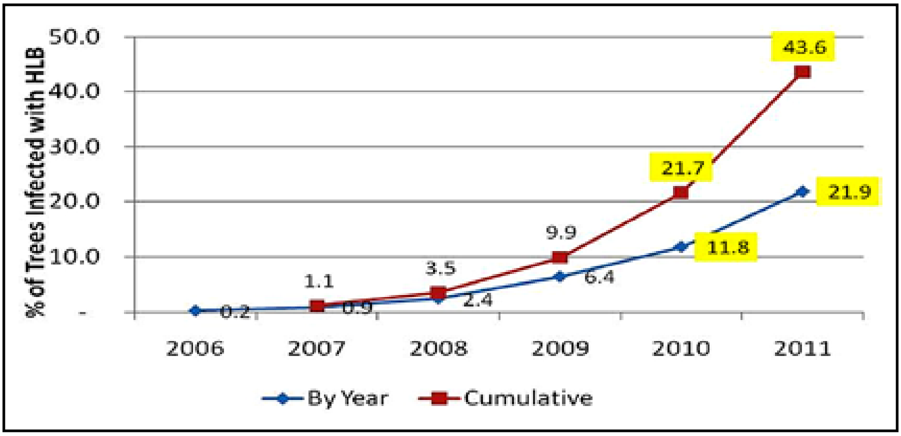

Figure 9. Estimated percent of trees infected statewide.

Nutritional Approaches

Nutritional approaches have been adopted on the basis of anecdotal evidence. There are many such programs, most of which are combinations of foliar nutritional applications, phosphorous acid, and compounds that are thought to be elicitors of systemic acquired resistance.[1] The goal is to maintain the productivity of existing trees. After spraying, the leaves absorb the nutrients and often look more healthy with less dieback. However, where these approaches have been tried in the past—in China and South Africa—they have not been successful over the long term.

Nutritional approaches cost more than pre-HLB growing costs, but less than psyllid control and roguing. On the other hand, the increased costs involved in nutritional approaches may be offset by circumventing scouting for psyllids and tree removal. But, whether using nutritional approaches or not, most growers are still attempting to control psyllids.

A major concern is that these alternative approaches are "forever" in that they involve acceptance of 100% infection, begging the questions of whether replanted young trees will grow and produce under high inoculum load and of how long the time horizon is until recovery is achieved. If psyllid control/roguing is chosen, the nutritional approach can also be employed later, but not the other way around.

Where Are We?

There are 8,000 citrus growers in Florida. Roughly 50% of the acreage is controlled by about 100 growers. A lot of the production is by small-area growers. There is consensus that the current losses result from HLB infection—with contributions from environmental stresses—and that the losses will continue to worsen. Initial replanting efforts have resulted in high levels of infection within 5 years, with no gain from nutritional approaches. Many groves—even those on nutritional programs—are beginning to decline.

[1]Analogous to the innate immune system in animals.

Some 15% of the Florida crop was on the ground in June 2013. If that's a trend, what losses will occur in 2014? Initial replanting efforts have resulted in high levels of infection in less than five years. In a newly planted 40-acre plot, we found 26% infection within 18 months. On the other hand, that was before we realized that the tolerance for the psyllid had to be less than zero.

The solution to this disease, will involve four concurrent processes:

- Research
- Regulatory approval
- Horticultural/agricultural production
- Consumer approval

They have to be tackled at the same simultaneously, because we are not dealing with a corn plant, we are dealing with a tree. When we have the solution, we must be in a position to commercialize it immediately. Several relevant research programs are in progress:

- Disease-resistant plants
  - — Texas A&M University
  - — Integrated Plant Genetics, Inc.
- Insect-resistant plants
  - — Cornell University
- Identification of synthetic resistance genes
  - — AgroMed LLC
- Gene delivery
  - — University of Florida
- Screening of potential genes.
  - — USDA

The major focus of the research is at Texas A&M, on the development of a disease-resistant tree. A second similar project is in progress at IPG, based in Gainesville. Development of an insect-resistant tree may be assisted by synthesis of resistance genes for which several delivery systems are being investigated. The research projects are at varying stages of completion; some are close to the identification of a commercial product. When we find the solution, it will be good for the industry as a whole; Southern Gardens will not monopolize it.

Gaining Deregulation

We are working closely with the federal agencies and have had multiple consultations since August 2006 with USDA-APHIS, EPA and FDA. The solution will involve a plant-incorporated protectant (PIP), therefore approval will be needed from all three agencies. With respect to the research here at Texas A&M, we will file for an experimental use permit (EUP) with the EPA as soon as possible.

An important question is, *How do we challenge the solution?* We have developed a rapid screening technique to identify resistant plants. In a greenhouse, plants grown under optimal conditions are exposed to infected psyllids. Susceptibility to disease is identified within 8 months, significantly more quickly than can be achieved in the field. Plants that appear to be disease-resistant in the greenhouse are then evaluated in regulated field trials. This confirmation of resistance is the first step towards commercialization, then we have to work through regulatory approval of the technology, for which it is necessary to generate a significant amount of data to satisfy all of the requirements of USDA, EPA and FDA to prove that the product is safe. We are working through that process.

Figure 10 provides a summary of what we expect to have to do; these tests are projected to cost in excess of $3 million. Multiple other aspects come into play. For example, three law firms in Washington, DC, are working with us on this process. It is important to remember that we are not a multinational company. We're a grower/processor, working with a network of people.

Study	Cost ($1000's)	Study	Cost ($1000's)
Recombinant protein production	300	Thermolability + in-vitro digestibility	100
Antibody production	100	42-day broiler	150
ELISA method development	100	90-day rat feeding (full tox profile)	275
ELISA Validation	125	90-day rat feeding - China (full tox profile)	75
Western method development	50	Human health risk assessment	50
Composition/Expression/ Agronomics	500	Protein equivalency – recombinant v. plant made	75
Southern blot	100	Non-target organisms and ecotoxicology	200
Sequencing	125	Honeybee toxicity	30
Within generation analysis	100	Non-target risk assessment	50
Efficacy	200	Product characterization (gene description, transformation, etc.)	25
Inheritance	50	Event PCR method	200
Acute oral mouse	100	Certified ref. materials (EU)	115
Aa homology search	50	**Total**	**3295**
Toxin homology search	50		

Figure 10. Summary of likely regulatory strictures imposed by EPA, USDA and FDA.

Consumer Acceptance

After the regulatory process is completed, we must ensure that the consumer accepts the product. As of today, our research indicates that the HLB greening disease cannot be solved without genetically engineering the tree. If citrus-greening resistance were to be obtained with a human transgene or one from a crab or a pig, the orange juice would never make it to the supermarket shelf. Even though the two genes being transferred to citrus are from spinach, the disease-resistant product will have to be marketed carefully.

Orange juice is in an interesting category. It's akin to "motherhood," so education will be fundamental to gaining consumer acceptance.

Benefits

The first and most important benefit is that the orange juice industry will survive in the United States. Although the Brazilians have the same disease, they have different regulations and larger growing areas, and they believe they can survive. Another major benefit will be the elimination of the insecticides now being used to control the insect that vectors the disease from infected to healthy trees. At this time, our groves are, essentially, insect-sterile because of the chemicals that we are applying to control the insect. When our genetic solution is put into practice, the impact on the environment will be huge.

The Future

Our task is daunting, but we have a good approach and our data show that we have good potential for resistance to citrus greening. On the other hand, at our present rate of progress, resistant trees may not be commercialized until 2019, which is not acceptable.

Figure 11. Typical fruit drop in 2013.

We must somehow speed up Mother Nature. If this year's fruit drop (Figure 11) is an indication of what's coming—if we lose 15 percent every year—we could lose the orange-juice industry. Texas and California are watching closely. California's challenge is more pressing because they produce fresh fruit. In Florida, we blend juice, whereas California cannot offer an infected orange for eating. Also, virtually every backyard in the state of California includes citrus trees, which will add to the difficulty of disease control.

It's a daunting task, but we've got an end goal in sight. Orange juice is not going to go away. Florida fruit is not going to go away. No other citrus-growing region can compare to Florida quality, day in and day out. But we have a significant job to do going forward.

Reference

National Research Council (NRC) (2010) Strategic Planning for the Florida Citrus Industry: Addressing Citrus Greening. Washington, DC: National Academies of Science.

Ricke Kress is president of Southern Gardens Citrus, a subsidiary of the US Sugar Corporation located in Clewiston. It is one of the largest growers of oranges in Florida and a major supplier of not-from-concentrate juice to the major brands and private-label grocery trade in the United States.

He graduated from Cornell University in 1973 with a BS in food science. His industry experience includes Libby's, Nestlé, Seneca Foods, and Northland Cranberries, Inc., in a variety of senior management positions from agriculture to sales and marketing.

Mr. Kress moved to Florida in 2005 to join the Southern Gardens Citrus management team. His arrival coincided with the occurrences of the current citrus-industry diseases, canker and greening. Southern Gardens Citrus and US Sugar have taken a proactive position in working with all factions of the state of Florida and the worldwide citrus industry in efforts to understand and deal with these disease challenges.

He serves on the Cornell University Institute of Food Science Advisory Council as well as the New York State Agricultural Experiment Station Advisory Council task force and is a past president of the Juice Products Association and Processed Apples Institute. Currently, he chairs the D. Glynn Davies Juice Products Association Scholarship program.